Dose-Response: An International Journal

Volume 8 | Issue 3 Article 11

9-2010

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*Dose-Response*, 8:384–386, 2010
*Formerly Nonlinearity in Biology, Toxicology, and Medicine*

ISSN: 1559-3258
DOI: 10.2203/dose-response.09-046.Cohen

International Dose-Response Society
www.Dose-Response.org

# LETTER TO THE EDITOR: RESPONSE TO EPA POSITION ON CANCER RISK FROM LOW LEVEL RADIATION

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The paper by J.S. Puskin (2009) on "Perspective on use of Linear-No Threshold Theory (LNT) for radiation protection and risk assessment by the U.S. EPA" begins its scientific section with the statement "Results from laboratory studies of irradiated animals and epidemiological studies of irradiated human cohorts are generally consistent with a linear, no-threshold dose-response, down to the lowest doses". With regard to animal studies, perhaps the clearest statistically indisputable violations of that statement are in the work at Argonne National Lab on injecting radioactive materials into mice (Finkel and Biskis 1962, 1968, 1969) and at Oak Ridge on gamma ray exposure of mice (Ullrich and Storer 1979). Another is tumor induction by irradiation of mouse skin throughout life (Tanooka 2001) where weekly irradiation with 1.5 Gy, 2.2 Gy, and 3 Gy resulted in tumors to 0%, 35%, and 100% of the mice respectively—hardly a linear no threshold response.

With regard to human studies, a clear and statistically indisputable demonstration of LNT failure was of bone cancers among dial painters and others occupationally exposed to ingested radium (Evans 1974) where there were no tumors in the several categories exposed to less than 10 Gy, but for dose ranges around 18 Gy, 35 Gy, 75 Gy, and 200 Gy 25% to 38% in each category developed tumors. Another case of LNT failure is the observation that lung cancer mortality in U.S. counties decreases dramatically with increasing mean radon levels in homes, with or without corrections for smoking prevalence and with full consideration of over 500 potential confounding factors (Cohen 1995, 2006).

The Puskin paper then presents a highly over-simplified theoretical basis for supporting LNT down to the lowest doses—the DNA damage is proportional to the number of radiation hits and hence to the dose. This ignores the many microarray studies (e.g. Yin et al 2005) which show that the genes affected by low level radiation are very different from those affected by the cancer-causing high levels from which risk estimates are derived (Tubiana and Aurengo 2005).

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But more importantly, Puskin's theoretical discussion deals almost exclusively with cancer initiating events, giving very little attention to processes induced by low level radiation that prevent such events from developing into a fatal cancer. He does list three low dose effects that could break down the linear response—bystander effect, genomic instability, and adaptive response—but concludes that the risk could be either increased or decreased by them. This conclusion may or may not be true for the first two items on his list, but it is definitely not true for adaptive response (UNSCEAR 1994), stimulated production of DNA repair enzymes. This protects against cancers induced by other causes (Azzam et al 1996, Ghiassi-Nejad et al 2002, Zaichkina et al 2003).

Other clearly protective processes are ignored by Puskin. Perhaps the most important is stimulation of the immune system by low level radiation (Liu 1992, Makinodan and James 1990, Sakamoto et al 1997, Liu 2003, Ina and Sakai 2005). This is being successfully used as a treatment for cancer (Sakamoto et al 1997). Other such processes include scavenging cancer-inducing corrosive chemicals out of cells (Yamaoka 1991, Yukawa et al 2005), apoptosis of damaged cells, and altered cell-cycle timing which gives more time for DNA damage repair.

Puskin ignores the fact that the latent period between exposure and tumor development is increased as exposure decreases (Dougherty and Mays 1969, Raabe 1994) such that tumors induced by low level radiation often would not develop before death from other causes. This alone, independently of all the above discussion, causes an effective threshold for radiation induced cancer.

More details on the arguments made above, and many more supporting examples are included in a recent paper (Cohen 2007).

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